B.VOGEL REVISION DATE: 5/28/93

TROUBLE-SHOOTING MANUAL - HASKEL GAS BOOSTERS

GENERAL INFORMATION:

INTRODUCTION

This manual is intended to provide users of HASKEL gas boosters with a better understanding of their function, proper selection criteria and system recommendations. It also contains a comprehensive guide for locating the cause of most service problems with a minimum of time and effort. Included are general descriptions (not part numbers) of recommended replacement parts or service required to correct the noted deficiencies.

STANDARD TERMINOLOGY

In order to make communications between the people involved with HASKEL boosters less confusing, a "standard" parts description is needed. Part numbers and model numbers are adequate for system assemblies, but the individual areas of the booster involved in trouble-shooting need "generic" descriptions applicable to all models in order to simplify the task of communication. The following descriptive names are recommended to facilitate transfer of information on booster problems.

AIR DRIVE:
The low pressure air driven section of the boster which moves the air drive piston alternately in opposite directions to power the gas section for generation of flow and pressure.

CYCLE:
One complete back and forth motion of the air drive piston. There are two strokes to a cycle.

STROKE:
The travel of the air drive piston from one end cap to the opposite end cap. A stroke is one-half of a cycle.

VALVE END CAP:
The air drive end cap containing the cycling valve and the pilot fill valve.

PILOT VENT END CAP:
The air drive end cap (opposite to the valve end cap) which contains the pilot vent valve.

AIR BARREL:
The cylindrical section of the air drive, between the two air caps, that guides the air piston and provides a surface for the piston seal.

AIR PISTON:
The low pressure piston in the air drive that connects to the gas plunger/piston and provides the reciprocating (back and forth) motion needed for compressing gas to produce pressure and flow.

PILOT FILL VALVE:
The normally closed, spring loaded pilot valve, located in the valve end cap, that pressurizes the pilot chamber when actuated open by the air piston.

PILOT VENT VALVE:
The normally closed, spring loaded pilot valve, located in the pilot vent end cap, that vents the pilot chamber when actuated open by the air piston.

AIR CYCLING VALVE:
The valve assembly used to direct the flow of air alternately to one side of the air piston and then the other, to produce the reciprocating (back and forth) motion needed to make the booster function.

SLEEVE:
The tubular portion of the cycling valve that contains the "porting" holes to direct the air to its proper destination, based on the position of the spool. This sleeve is sealed against "lands" in the valve end cap to partition the flow passages.

SPOOL:
The moving portion of the air cycling valve that is controlled by the pilot valves pressurizing and venting the pilot chamber at one end of the spool. The "O" rings on the spool "partition" the flow to direct it to the proper passages in the sleeve to cycle the air piston.

FLOW TUBE:
The flow tube routes the drive air from the valve end cap to the opposite end cap to provide pressure for the stroke towards the valve end cap. It also provides the path for venting the drive air from that side of the piston at the end of the stroke.

PILOT TUBE:
The pilot tube connects the pilot chamber to the pilot vent end cap. When the air piston actuates the pilot vent valve open, it vents the pressure in the pilot chamber and shifts position of the cycling valve to reverse the direction of the air drive piston.

GAS SECTION:
The section containing the gas barrel, plunger/piston, seal package and check valves. All parts of this section are exposed to the compressed gas. Therefore, all materials used must be compatible.

GAS BARREL/END CAP:
The structural section of the booster. It contains the high pressure seal package and check valves.

PLUNGER/PISTON
The part, mechanically connected to the air piston, that moves back and forth in the gas section of the pump to produce pressure and flow.

HIGH PRESSURE SEAL:
The plunger, piston, or rod seal in the gas section that seals the pressure to contain the compressed gas. This seal may be a single part or a combination of parts, and is installed with bearings and backups as required to provide a "seal package" capable of resisting the pressure generated.

INLET CHECK VALVE:
The check valve, located in the gas section, that permits entrance of the gas on the "suction" stroke, and closes to trap gas in the gas section for the "boosting" stroke.

OUTLET CHECK VALVE:
The check valve, located in the gas section, that permits gas to go into the downstream system during a "boosting" stroke and closes to prevent return of the gas during the "suction" stroke.

FLOW:
The amount of gas forced into the downstream system. The amount is usually stated in "standard cubic feet per minute" (SCFM), or "liters per minute" (LITERS).

BOOSTER AREA RATIO:
The "ACTUAL" booster ratio is the number obtained by dividing the area of the air barrel I.D. by the area of the gas barrel bore diameter.

To obtain the "NOMINAL" booster ratio, a friction multiplying factor is applied. For example, if the "actual" ratio is 33 and the friction factor chosen is 10 percent, then the "nominal" ratio is 30 (33 x 90 percent). This number is normally used to determine maximum attainable pressure.

STALL:
When the booster has reached its "maximum pressure". the air drive force is equal to the sum of the pressure force and the friction in the gas section. Under this condition, there is no "unbalance" of forces left to drive the booster, and it stops cycling. This condition is referred to as "stall", and can be used as an automatic "safety" limiter by proper setting of air drive pressure.

SEPARATION:
A vented section located between the air drive piston rod seal and the gas section rod seal to prevent direct leakage from the air drive into the gas section. All **HASKEL** gas boosters have separation.

SINGLE-ACTING BOOSTER:
A booster that takes in gas on one stroke of the cycle and discharges it on the other stroke.

DOUBLE-ACTING BOOSTER:
A booster designed to discharge gas on both strokes of the cycle. Depending on the check valve arrangement, the input (suction) of boosted gas can be on both strokes or only one.

TWO STAGE BOOSTER:
A booster that has two pumping sections of different nominal ratios operating with a single air drive. These two sections are normally at opposite ends of the air drive. There is usually a "lower" ratio, high volume end for maximum displacement, and a "higher" ratio low volume end for generating final pressure.

SINGLE ENDED GAS BOOSTER:
A booster which has the gas section only on one end of the air drive. It may be single acting (as in the "AG-15") or double acting (as in the "AGD-4")

DOUBLE ENDED BOOSTER:
A booster having gas sections on both ends of the air drive. It may be "Single Stage" (as in the AGD-15) or "Two Stage" (as in the AGT-15/30).

UNSWEPT VOLUME:
The minimum volume left in the gas section on completion of the compression stroke. This volume will normally be at system pressure when in operation. (The minimum volume is due to clearances, porting, and check valves.)

VOLUMETRIC EFFICIENCY:
Gas is compressible. Because of the "unswept volume" in the gas section, it is impossible to "inhale" the actual displacement of the booster. This volume must expand enough to lower the pressure below supply pressure before new gas can enter the gas section. As the system (outlet) pressure increases, the "loss" of effective displacement per cycle increases, and the "volumetric efficiency" decreases. When the pressure in the unswept volume is high enough, it will take the full stroke to get down to inlet pressure and the efficency becomes "zero". The inlet/outlet pressure ratio has reached its maximum and it will not inhale or transfer gas even though it may still continue to cycle.

MAXIMUM COMPRESSION RATIO:
Because of the "volumetric efficency" effects due to the gas compressibility and the "unswept volume", **maximum pressures attainable with gas boosters are not completely defined by the nominal booster ratio and the air drive pressure.** The "Maximum Compression Ratio" is defined as the ratio at which the "volumetric Efficiency" becomes "zero".

INTERSTAGE STALL:
Occurs only on "Two Stage" boosters when the "first stage" stalls because it cannot transfer its gas into the "second stage" without reaching stall pressure. Gas will increase in pressure in proportion to the amount it is compressed and if the supply pressure to the first stage is too high, The compression ratio between stages can result in an interstage pressure that exceeds the capability of the first stage. The booster will then stop cycling.

Interstage stall does not happen suddenly. When pressurizing a receiver from a gas supply, the booster will slow down as the system pressure approaches the stall pressure of the first stage. It will only stall when the system pressure exceeds that value, because the second stage is still able to discharge some gas into the system until stall pressure is reached.

MAXIMUM SUPPLY PRESSURE:
Applicable only to "Two Stage" "Double Ended" gas boosters. The maximum supply pressure is the pressure which will result in "Interstage Stall" at the design operating conditions. For practical application, it is best not to exceed 75% of this pressure in actual service in order to maintain reasonable flow rates.

FUNCTIONAL DESCRIPTION:
HASKEL air driven Gas Boosters incorporate three basic functions. (1) The **air drive** which supplies the power for gas compression, (2) the **cycling system,** which controls the reciprocating (back and forth motion) , and (3) the **gas section** which provides the flow of gas. These three functions work together to provide proper operation. Damage or contamination, affecting any one of the functions, can result in eratic operation and/or compromised performance.

HASKEL air driven Gas Boosters are "ratio" devices using low pressure air against a large piston area to generate force (force= pressure * area). This force is transmitted through a smaller area plunger or piston in the gas section to increase the pressure of a gas by a factor equal to the nominal area ratio between the air drive and the gas piston/plunger. Using this principle, a large, low pressure air flow can be used to generate a smaller higher pressure gas flow.

AIR DRIVE FUNCTION:
The cycling system, built into the air drive end caps, provides the continuous reciprocating action of the booster. It is composed of an air piston assembly, two pilot valves, and an air cycling valve. The action of the valve depends on an "unbalance" of areas exposed to the drive pressure and the pilot pressure. With the pilot pressure vented, the air drive pressure works against an area of the valve spool to move it to a position routing the air through a flow tube to the pilot vent end cap. This drives the air piston towards the valve end cap. When the air piston contacts and opens the pilot fill valve in the valve end cap, the pilot chamber is pressurized. This pressure, acting on a larger area of the spool than the drive air, moves the spool to its other position. In this position, the pressure on the air piston is shifted to drive the piston towards the pilot vent end cap. When it reaches the cap, it opens the pilot vent valve, permitting the pilot chamber to vent (through the pilot tube) and shift the spool to its original position. The cycle of pressurizing and venting the pilot chamber continues to repeat automatically as long as air pressure is available and the outlet pressure is below stall pressure.

GAS SECTION FUNCTION:
The gas section consists of a gas barrel to contain the pressure, a plunger or piston to move the gas, and check valves to control the flow direction. The size and shape of this section will vary with the size of the air drive, the nominal booster ratio, and the check valve configuration. Its operational mode is basically the same for all gas boosters.

The plunger/piston is mechanically connected to the air drive piston and extends through a separation area into the gas section. The reciprocating (back and forth) movement of the plunger/piston alternately increases and decreases the volume in the gas barrel (the difference between the two volumes is the displacement per cycle). When the volume is being increased (suction stroke), the "unswept volume" in the gas section must expand until the residual pressure is lower than the supply pressure, and then the inlet check valve opens and gas enters the gas barrel. When the plunger/piston reverses direction, the inlet check valve closes to trap the gas, and the outlet check valve opens to direct the flow into the downstream system (compression stroke). When the stroke is complete and another suction stroke is started, the outlet check valve closes. This prevents system gas from returning (back flowing) into the gas section. The process is repeated automatically each cycle until a force/balance condition is achieved between the drive force of the air drive and the downstream pressure on the plunger/piston (stall).

The "**output flow**" is the result of piston/plunger displacement. The "**pressure**" is generated by system resistance (back pressure), not the total force available. The "excess" force available over that required to generate pressure is used for "**cycle rate**", and influences the output flow. With no back pressure, all of the energy is used for cycle rate, and it will cycle rapidly. As the system builds in pressure, the excess energy decreases, and the pump will cycle progressively slower until it reaches the "force balance" point and then it will stop (stall), because all of the energy is required to generate the desired pressure.

Stopping the booster traps and holds the downstream pressure. The maximum outlet pressure produced by these boosters is a function of the "nominal ratio", the "maximum compression ratio" and the air drive pressure. For example, an AG-30 (Nominal 30:1 ratio; max compression ratio 28:1) booster with 100 psi air drive and 200 psi supply will develop 3000 psi at the stall condition. Note that if the supply pressure were only 100 psig, the maximum pressure attainable would be about 2800 psig (maximum compression ratio), and the unit would continue to cycle slowly. When the maximum compression ratio is reached, and it is less than the stall pressure, the booster cannot inhale new gas on the suction stroke. This is because the pressure in the "unswept volume" is so high that it cannot expand enough to lower the gas section pressure below supply pressure. The booster then continues to compress and expand the same residual gas and it does not flow into the downstream system.

In the stall condition, if the downstream pressure is reduced due to leakage, the use of gas downstream, or if the air drive pressure is increased, the boosting action will re-start automatically because the forces are no longer "balanced". This is an advantage in any application requiring extended periods of constant pressure, because there is no power used at stall as would be required by an electric or hydraulic motor drive that must run continuously.

BOOSTER SELECTION CRITERIA:
Air driven gas boosters have six significant operating parameters that determine their selection for any application. These are as follows:

a. Flow rate required for system operation.
b. Pressure ratio required to generate desired system pressure.
c. Air drive pressure available (PSI).
d. Air supply flow capability (SCFM).
e. Type of gases to be boosted (selection of proper seals and structural materials)
f. Gas supply pressure available.

The selection of the proper booster for any application starts with determining which booster "series" will provide the amount of flow required. This can be determined from the flow vs pressure curves provided in the "Rapid Reference Performance Data Book" (bulletin No. 860629). The possible ratios for the application are determined by examination of the performance data for the boosters using the air pressure and air flow available. The ability of the booster to generate pressure is a function of the drive pressure, the nominal ratio, and the maximum compression ratio. The ability to generate flow is a function of the quantity of air available to drive it, the displacement per cycle of the pump, and the volumetric efficiency. Within each booster series, there are standard materials of construction available. For applications involving aggressive gases, some material substitutions may be possible.

There are many optional modifications available for specialized conditions, and these options must be evaluated after the booster selection is made.

For applications involving "high purity" gases, it may be desireable to have a "purge" or "positive pressure" applied to the "separation" area to eliminate the possibility of contamination by environmental air.

SYSTEM DESIGN CONSIDERATIONS:

The most important factors in maintenance of any mechanical equipment are proper selection and proper system installation. Boosters should be selected to provide the best match for the application (flow rate, pressure rating, gases used, and type of duty, etc.).

The system should provide inlet filtration on both air and gas supply lines to prevent particulate contamination from damaging seals and sealing surface finishes.

Permitting boosters to operate "unloaded" for extended periods of time can result in excessive seal wear and higher maintenance cost, as well as shortening its useful life. Running "unloaded" is equivalent to taking your car out of gear at full throttle...not very good for service life. Throttling the air drive supply during lightly loaded conditions will give better seal life.

Provide an adequate supply of gas to compensate for system usage. With a fixed supply volume, depletion can cause lowering of supply pressure to the point that "maximum compression ratio" and "volumetric efficiency" can affect its ability to recharge the system in a timely manner.

For applications involving "high purity" gases, downstream filtration is recommended since no dynamic seal (one that is moving with respect to the mating part) can be "particle free".

Supply piping for the air drive and gas sections should be at least the size of the connections to obtain the rated catalog performance of the booster. Too small a line size on the air drive supply will result in slower operation and less output. Too small a gas supply line can cause "starvation" (incomplete filling of the gas barrel), and failure to meet the expected flow rates. Too small a down-stream line will cause excessive resistance, making the booster think it working against a higher system pressure, and it will slow down accordingly and put out less flow.

Where the booster pressure capability is greater than the system design pressure, a relief valve should be installed with adequate flow capacity to prevent over-pressurization.

TROUBLE-SHOOTING MALFUNCTIONS:

In order to minimize the time and effort used to find the "cause" of a booster malfunction, it is best to look at the symptoms, and check the "easiest" things first, progressing to dis-assembly, if required. Parts should only be replaced if it is determined that they are the cause. In order to do this, sections "B" through "L" will discuss and outline the "method" to be used (for each booster series) to fix problems with a minimum of parts and labor.

OPERATIONAL INFORMATION - 5 3/4 INCH DRIVE "AG" AND "AGD" SERIES (1.5 H.P.) SINGLE ACTING BOOSTERS

The following sections will give explanations and methods for trouble-shooting this series of boosters for the malfunctions noted. Each section will examine symptoms and indicate which things to check, so that dis-assembly and parts replacement are minimized.

1. External Leakage
2. False Cycling
3. Will Not Cycle
4. Will Not Stall
5. Will Not Hold System Pressure Without Drive Air
6. Erratic Cycling or Slowdown
7. Does Not Meet Expected Flow Rates at Cycle Rate

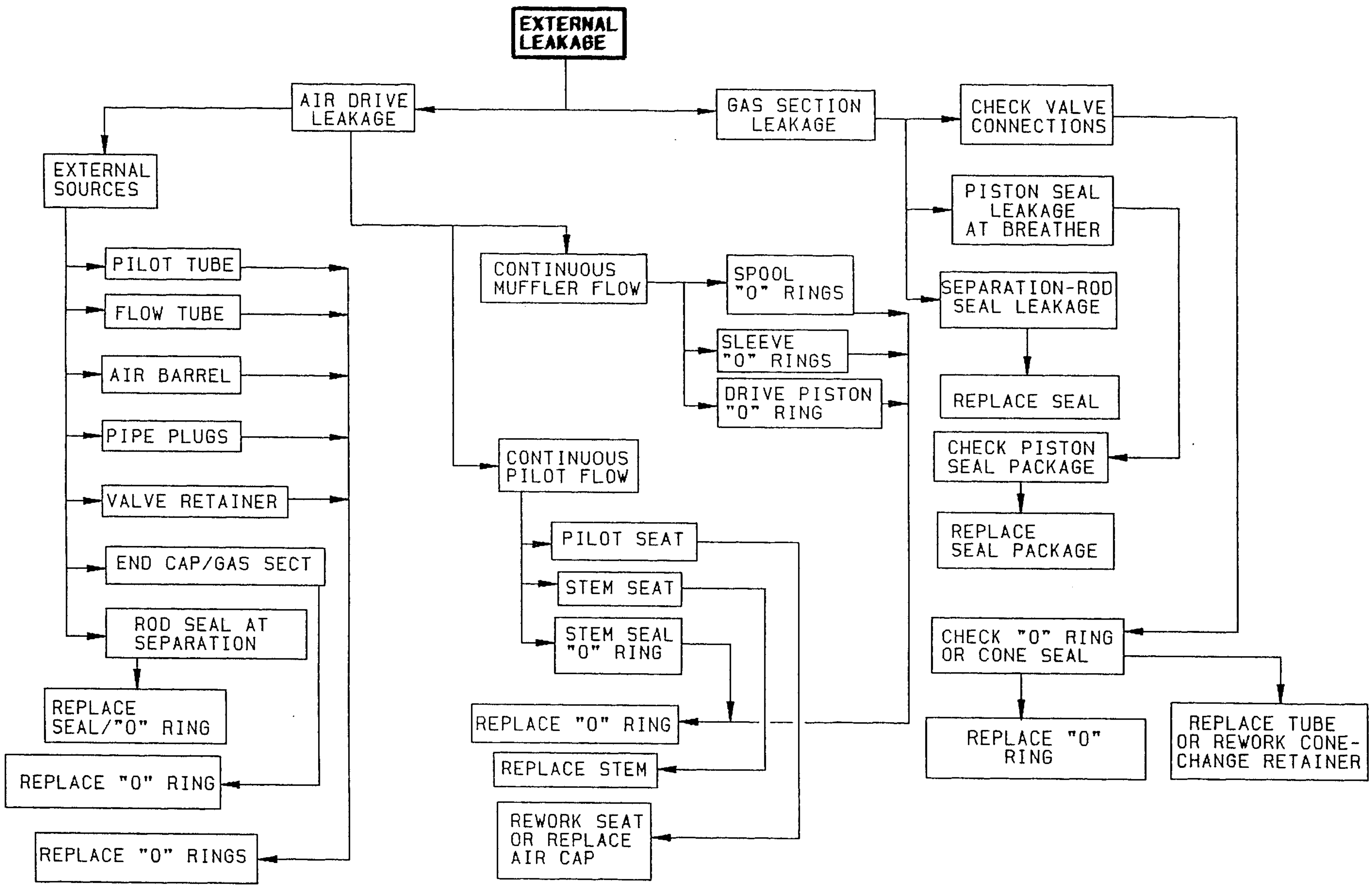
EXTERNAL LEAKAGE:
External leakage is always the result of a defective seal, and can be from the air drive (air or gas leakage), or the pumping section (gas only) leakage. This can cause operational, as well as corrosive and toxic problems, depending on the gas being boosted. In general, external leakage of pumped gas is unacceptable, and must be corrected. External leakage of the air drive may be symptomatic of a condition that could result in a later problem. If the booster is to be driven by "sour gas", then it can be a toxic hazard. In that application, all normal vent ports are piped together and routed to a safe disposal area.

AIR DRIVE LEAKAGE:
Air drive leakage can be detected by the use of "bubble soap" or audible noise if the leak is large enough. "Cyclic" venting through the mufflers and pilot vent port is a "normal" condition for a "standard" booster, and is not a concern unless it becomes "continuous". For boosters with the "severe service cycling modification", there will be some continuous venting from the mufflers, since the teflon air piston seal does not seal as well as the "O" ring. The following sequence should be used to determine the location of the leakage.

1. If leakage is audible, it is most likely large enough to be located by "feel" of the air flow coming from the leak. If there is no "audible" leakage, then bubble soap should be used, carefully, for locating the suspected leak point. The possible areas to check include:
    a. Pilot tube "O" rings
    b. Flow tube "O" rings
    c. Air barrel "O" rings (at end caps)
    d. Pipe plug (1/2 inch) on lower cap sealing pilot chamber.
    e. Valve retainer at exhaust end of cycling valve.
    f. Connection of gas section to air drive valve end cap. For "distance piece" pumps, leakage out of the rod seal or body seal of the distance piece.
    g. Continual flow (in addition to the normal cyclic flow from the mufflers) can be caused by spool "O" ring damage, Sleeve "O" ring damage, or air drive piston "O" ring leakage, and will require some dis-assembly to determine the exact cause.
    h. Continual flow (in addition to the normal cyclic flow) from the pilot vent port on the upper cap can be caused by pilot seat damage in the upper cap, damage to the pilot stem molded rubber insert, leakage of the stem seal "O" ring, or contamination on the seating surface.

GAS SECTION LEAKAGE:
Gas section leakage is normally easy to detect. It can be due to the **static external seals** on the gas end cap, or the **dynamic piston/plunger seal.** If it is the static seals, a bubble soap check of the joints where the seals are located will show the leaking area. If it is the dynamic "rod" seal, then the leakage can be detected at the rod seal "drain" port between the air drive and gas section. If it is the Piston seal, then the leakage can be detected at the vent port above the gas barrel (this port normally has a plastic "breather" installed to prevent entrance of particulate that could damage seals and surface finishes). In either condition, the defective seal package should be replaced, after it has been determined that there is no damage to the sealing surfaces. Also, visually inspect to determine if externally induced contamination from the pumped gas could have damaged the seal.

See flow chart for a quick overview of all trouble-shooting sequences.


EXTERNAL LEAKAGE
AIR DRIVE LEAKAGE
GAS SECTION LEAKAGE
CHECK VALVE CONNECTIONS
PISTON SEAL LEAKAGE AT BREATHER
SEPARATION-ROD SEAL LEAKAGE
REPLACE SEAL
CHECK PISTON SEAL PACKAGE
REPLACE SEAL PACKAGE
CHECK "O" RING OR CONE SEAL
REPLACE "O" RING
REPLACE TUBE OR REWORK CONE-CHANGE RETAINER
EXTERNAL SOURCES
PILOT TUBE
FLOW TUBE
AIR BARREL
PIPE PLUGS
VALVE RETAINER
END CAP/GAS SECT
ROD SEAL AT SEPARATION
REPLACE SEAL/"O" RING
REPLACE "O" RING
REPLACE "O" RINGS
CONTINUOUS MUFFLER FLOW
SPOOL "O" RINGS
SLEEVE "O" RINGS
DRIVE PISTON "O" RING
CONTINUOUS PILOT FLOW
PILOT SEAT
STEM SEAT
STEM SEAL "O" RING
REPLACE "O" RING
REPLACE STEM
REWORK SEAT OR REPLACE AIR CAP

FALSE CYCLING: (RAPID SHORTENED STROKING)(MACHINE-GUNNING)
SYMPTOMS:

a. Unexpectedly rapid cycling under load.
b. Back pressure does not have significant effect on cycle rate.
c. Failure to build pressure as expected from cycle rate.

THEORY OF CAUSE:
The reasons for "false cycling" of the air cycling valves are either "LEAKAGE INTO" OR "LEAKAGE OUT OF" the pilot system. The pilot system operates with a constant pressure on the annular area at the small end of the spool and an alternating pressurizing and venting of the large end of the spool.

When the large end of the spool is vented, if there is any leakage "into" the pilot system, it will cause the spool to shift to the energized position. This will result in the piston not completing its stroke and "re-cycling" to the pilot vent cap to "vent" the pilot for another stroke. The booster, therefore, does not put out as much flow during each partial cycle.

When the pilot chamber is pressurized (energized), and there is a leak "out" of the pilot system, the pump does not complete its stroke and it returns to the valve end cap to get re-pressurized. This will also result in lower flow as noted above.

If the leakage is severe, the cycling can be extremely rapid in both cases. This will definitely affect the service life of the pump and seals.

TROUBLE SHOOTING METHODS:

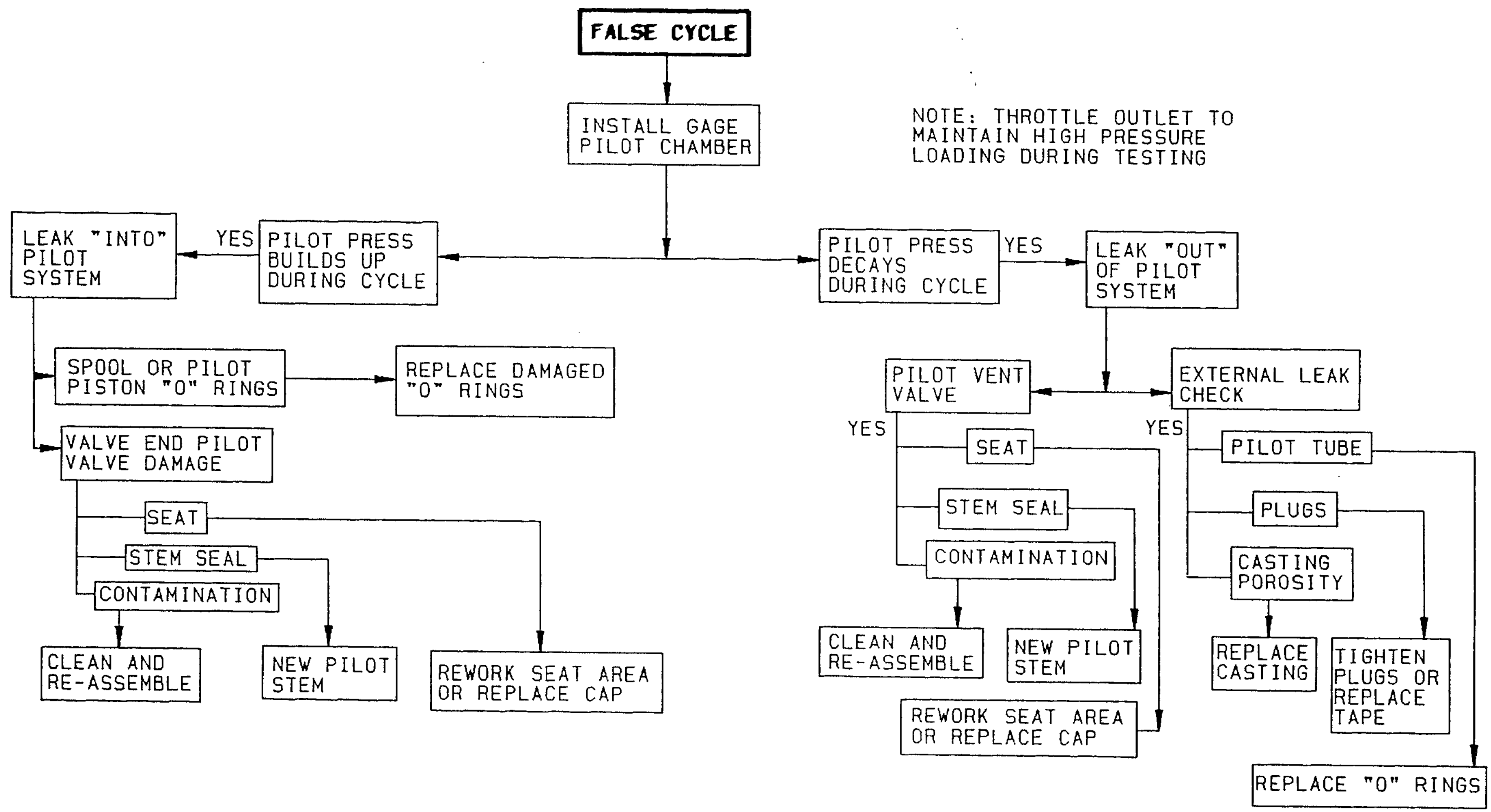
a. The first thing to do if "false cycling" is suspected, is to install a small pressure gage (0-180 psig) into the pilot chamber to monitor the pressure during cycling. (This is accessed by removing the 1/2 inch pipe plug at the large end of the cycling valve and installing a guage with a pipe bushing. Be sure that there is no leakage at the connection, since that can "cause" the problem which is being diagnosed).

b. With the outlet severely restricted, but not shut off, cycle the booster slowly using a "speed control valve" on the air drive supply and monitor pilot pressure. The pilot pressure should increase rapidly when the piston contacts the pilot fill valve and maintain a relatively constant value until it contacts the pilot vent valve at the opposite air cap. Note that the pilot chamber pressure during cycling will vary from "more than half of the drive pressure" to "less than half of the drive pressure. It will never be completely vented or completely pressurized. This is because it only takes in enough pressure or vents enough pressure to unbalance forces and shift spool position. Once the spool has shifted, the piston moves away from the pilot valve stem, and no further pressure changes should occur.

If the pressure increases or decreases significantly during each part of the cycle, then note whether there is a periodic venting at the vent port on the pilot vent end cap. If there is **no** venting, then the leakage is "out" of the system (external) and the stroking is incomplete at the valve cap end before turn-around. If there is cyclic venting at the pilot vent port, then the leakage must be "into" the pilot system by an internal leak, and the booster is making an incomplete cycle at the pilot vent end cap.

c. If the leakage is determined to be "external", then use bubble soap to determine its location. It could be an "O" ring seal or casting porosity. Gross leakage to cause very rapid cycling is usually caused by a damaged "O" ring. It is also possible that the pilot valve may be leaking due to seat damage or contamination.

d. If the leakage is "internal", it may be caused by contamination or damage to the pilot stem seal on the valve end cap, or damage to the pilot valve seat in the valve end cap. It is also possible that the "O" rings on the large end of the cycling spool or sleeve may be damaged, and permit drive air pressure to bleed into the pilot chamber.



FALSE CYCLE
INSTALL GAGE PILOT CHAMBER
NOTE: THROTTLE OUTLET TO MAINTAIN HIGH PRESSURE LOADING DURING TESTING
PILOT PRESS BUILDS UP DURING CYCLE
YES
LEAK "INTO" PILOT SYSTEM
SPOOL OR PILOT PISTON "O" RINGS
REPLACE DAMAGED "O" RINGS
VALVE END PILOT VALVE DAMAGE
SEAT
STEM SEAL
CONTAMINATION
CLEAN AND RE-ASSEMBLE
NEW PILOT STEM
REWORK SEAT AREA OR REPLACE CAP
PILOT PRESS DECAYS DURING CYCLE
YES
LEAK "OUT" OF PILOT SYSTEM
PILOT VENT VALVE
YES
SEAT
STEM SEAL
CONTAMINATION
CLEAN AND RE-ASSEMBLE
NEW PILOT STEM
REWORK SEAT AREA OR REPLACE CAP
EXTERNAL LEAK CHECK
YES
PILOT TUBE
PLUGS
CASTING POROSITY
REPLACE CASTING
TIGHTEN PLUGS OR REPLACE TAPE
REPLACE "O" RINGS

WILL NOT CYCLE:
SYMPTOMS:
Air pressure to the drive does not cause the booster to start cycling.

THEORY OF CAUSE:
The air drive pressure is used for driving the main air piston and for shifting the cycling valve by pressurizing and venting the pilot system cavity. Because of the large forces involved with the air drive piston, it is unlikely to be the cause of the inability to cycle. The cycling spool, using relatively low pressure and small surface areas, has very low forces driving it. Therefore it does not take much restraining force to stop it.

The most common causes of inability to cycle are as follows:

a. Drying out of lubrication on the spool "O" rings due to an extremely "dry" air supply.
b. Washing out of the lubrication on the spool "O" rings due to excessive water in the air supply.
c. Contamination in the air cycling valve sleeve causing the spool to be "jammed" by particulate interference.
d. Swelling or damage of "O" rings due to presence of "incompatible" gases. (i.e.- Sour gas, carbon dioxide, etc)
e. If the pilot valve stems are too short and do not get enough travel to open properly, it can also cause an inability to cycle. This condition usually occurs after an overhaul, where there are two different length pilot stems that have accidentally been switched.
f. Lack of a separate pilot pressure source for pumps equipped with the "remote pilot modification". It can also happen if the unit is equipped with an air pilot switch that is "normally closed" and set to open at some higher pressure.

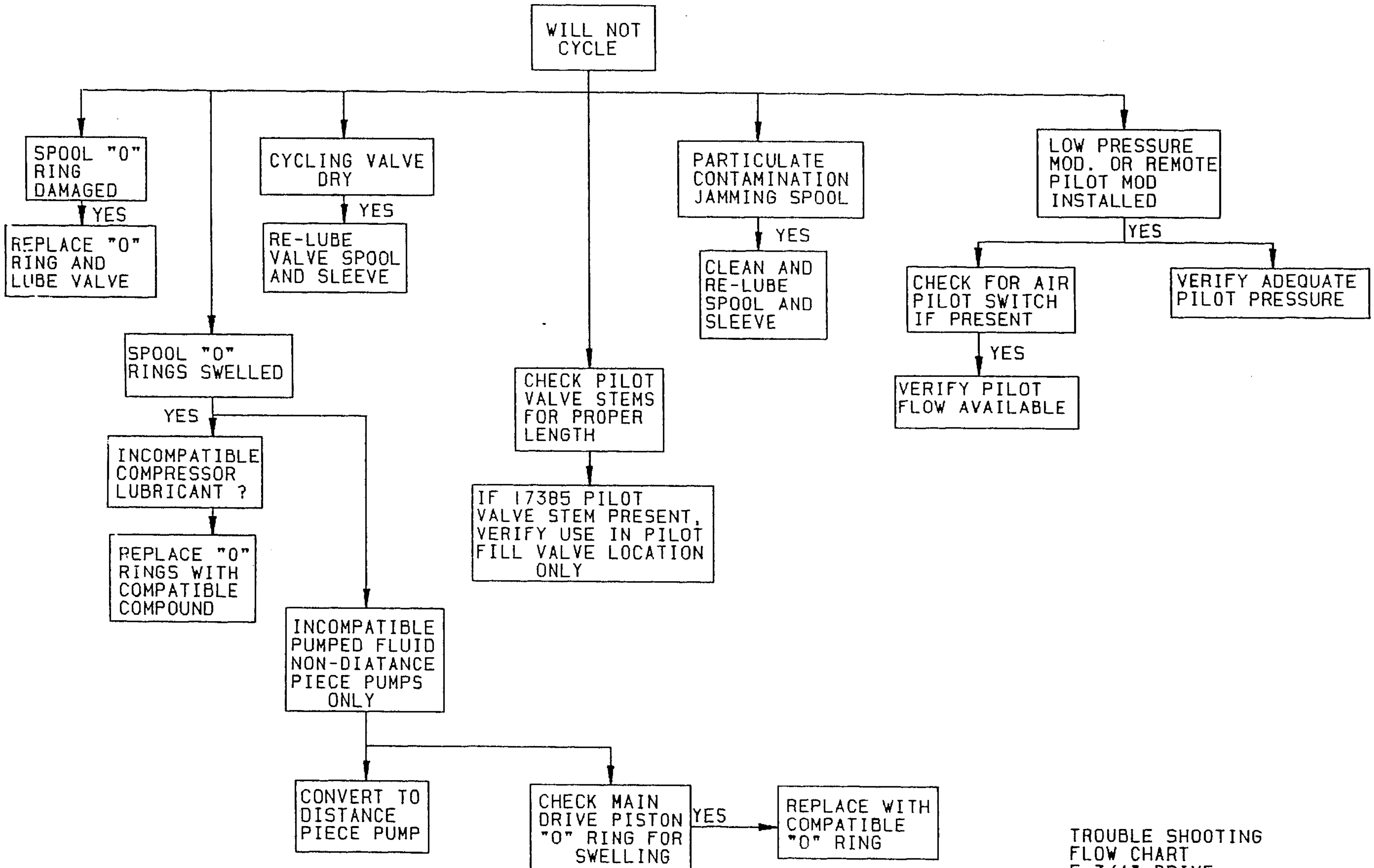
TROUBLE SHOOTING METHODS:
For items a and b, remove retaining cap and cycling spool and inspect "O" rings for wear or damage. Replace "O" rings as required. Re-lubricate with Haskel lubricant (from seals kit), and re-assemble.

For item c, remove retaining cap, spool and sleeve, and clean thoroughly with solvent. Inspect for "O" ring damage. Replace seals as required. Re-assemble with Haskel lubricant.

For items d, determine if "O" ring seals have been swelled by compressor air. Determine what is the proper "O" ring compound that will satisfactorily resist this fluid, and replace seals, lubricate and re-assemble.

For item e, check assembly drawing to verify proper location of stems. Switch stems, if necessary, to verify proper placement.

For item f, verify whether a "remote pilot" modification has been installed in the pump. Usually, this deletes the 1/8" plug located just adjacent to the 1/2" pipe plug at the end of the cycling valve. If that port is open, it most likely needs a separate pilot air pressure supply to match the drive pressure (or 40 psig minimum with the "low pressure" modification).



TROUBLE SHOOTING
FLOW CHART
5 3/4" DRIVE
B. VOGEL 1/2/92

WILL NOT STALL:

SYMPTOM:

BOOSTER WILL NOT STOP CYCLING WHEN OUTLET IS BLOCKED OR STALL PRESSURE IS ACHIEVED.

THEORY:

The reasons for a single or double acting booster to continue cycling after system shut-off or acheiving stall pressure has been reached are as follows:

a. System leakage. (may be external or internal in a component).
b. Internal or external booster seal leakage.
c. False cycling of booster.
d. Maximum compression ratio has been exceeded.

When the booster has completed a suction stroke, it can only complete the cycle if it can "dispose" of the fluid. Since we are dealing with a compressible fluid, the options are a little different than with a liquid pump. The "disposal" can mean compression without generating enough pressure to open the outlet check valve against system pressure. This occurs when the "maximum compression ratio" is exceeded. The booster has a certain amount of "unswept volume" because of the need to account for tolerances and geometry of the parts. At the end of the compression stroke, this volume contains system pressure. On the suction stroke, after compression, this volume must expand to lower the pressure to less than supply pressure in order to take in additional gas. If the stroke is insufficient to create this expansion, the booster will continue to cycle at a slow rate and re-compress the same charge of gas with no outlet flow. For best operating efficiency, it is recommended that the actual compression ratio used in service be limited to 6:1. Any compression ratio, up to the maximum listed in the catalog, will give flow, but at a progressively decreasing amount. This will result in excess usage of drive air for the amount of gas transferred.

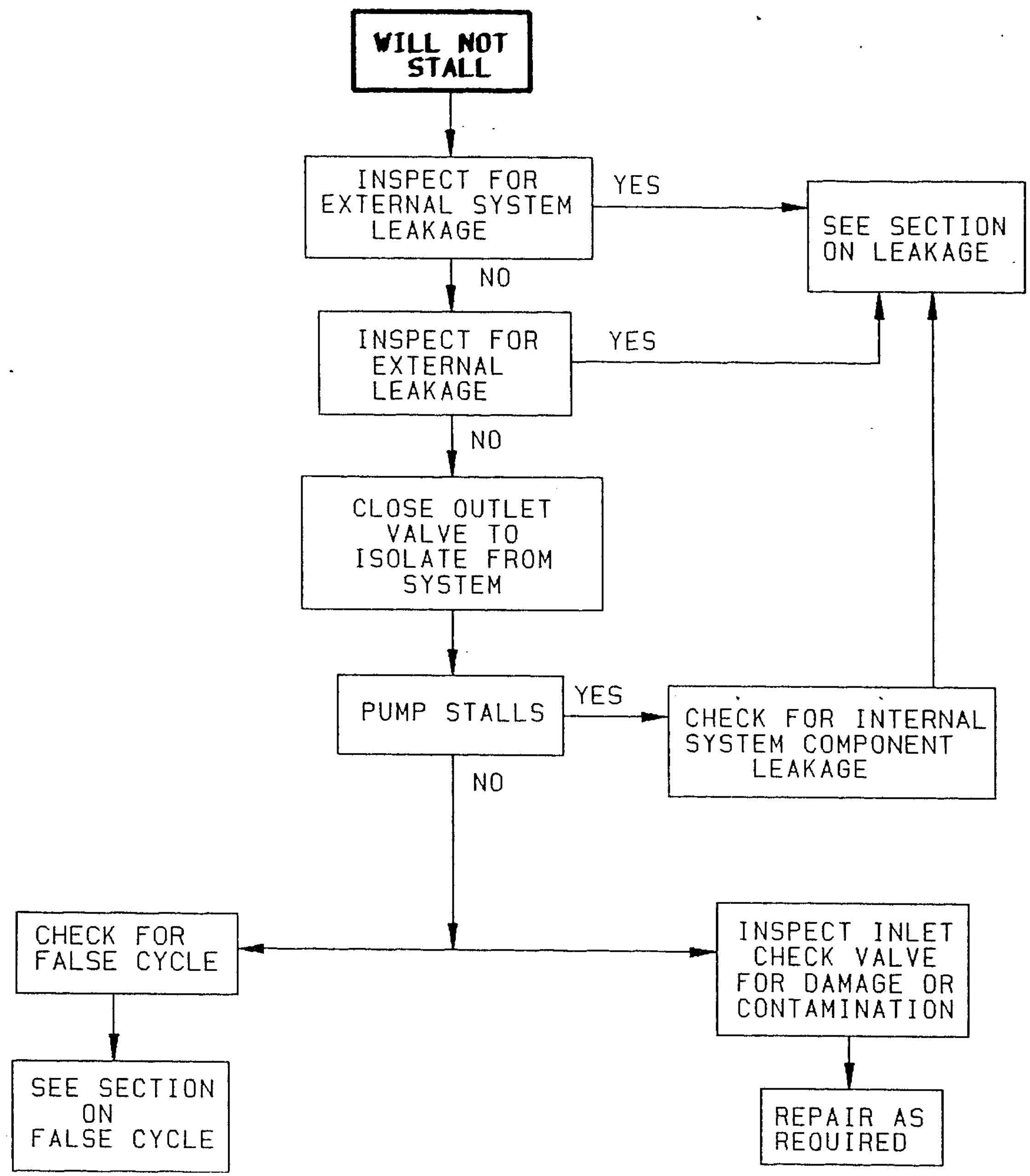
TROUBLE SHOOTING METHOD:

For item a, check the system shut-off valve or operational device (i.e.- cylinder, receiver, etc) for possible leakage. The system should be eliminated as a source of the problem before trouble shooting the booster.

For item a. and b., see section on "Leakage"

For item c. see section on "False Cycling"

For item d. check actual compression ratio (outlet press+15/inlet press+15). Value must be less than specified maximum.



WILL NOT STALL
INSPECT FOR EXTERNAL SYSTEM LEAKAGE
YES
SEE SECTION ON LEAKAGE
NO
INSPECT FOR EXTERNAL LEAKAGE
YES
NO
CLOSE OUTLET VALVE TO ISOLATE FROM SYSTEM
PUMP STALLS
YES
CHECK FOR INTERNAL SYSTEM COMPONENT LEAKAGE
NO
CHECK FOR FALSE CYCLE
INSPECT INLET CHECK VALVE FOR DAMAGE OR CONTAMINATION
SEE SECTION ON FALSE CYCLE
REPAIR AS REQUIRED

WILL NOT HOLD PRESSURE WITHOUT DRIVE AIR:

SYMPTOMS:

Venting drive pressure results in a momentary drop in system pressure, or a steady rapid decline in system pressure, with a small system volume). Larger system volumes will not be as noticeable, since a small gas leak will take a longer time to show the effect because of gas compressibility.

THEORY OF CAUSE:

In a "normal" situation with a "leak free" system and a "good" booster, the system pressure will have no significant decay when the booster is stopped and the air drive vented. (Note that the booster check valves are designed for operation of the <u>booster</u>. Long duration sealing is NOT a requirement. Therefore, it should not be used for "long duration" maintenance of system pressure when the booster is not operational. If this is desired, an additional check valve or shutoff valve should be installed to isolate the booster when not in use). The outlet check valve will prevent return of transferred gas, and a "leak free" system will prevent pressure loss. Pressure will remain relatively constant, except for a slight decrease due to cooling. Since gas leakage in the system CAN occur, it is necessary to eliminate that possibility before looking for booster problems. The following items can cause the condition:

a. <u>System external leakage</u> (loose or defective fittings)

b. <u>System internal leakage</u> (through valve seats, cylinder piston seals or relief valves)

c. <u>Booster outlet check leakage</u> (can cause momentary drop, but not continued rapid decline in pressure, for small system volumes, since only booster displacement and piston seal leakage is available as a leak path for the system gas)

d. <u>Booster outlet AND inlet check valve leakage</u> (will cause momentary drop and continued rapid decline in pressure for small system volumes, as gas leaks through both check valves back to the gas supply line.

TROUBLE SHOOTING METHODS:

Adjust air drive pressure to the value which will just barely maintain sytem pressure (stall).

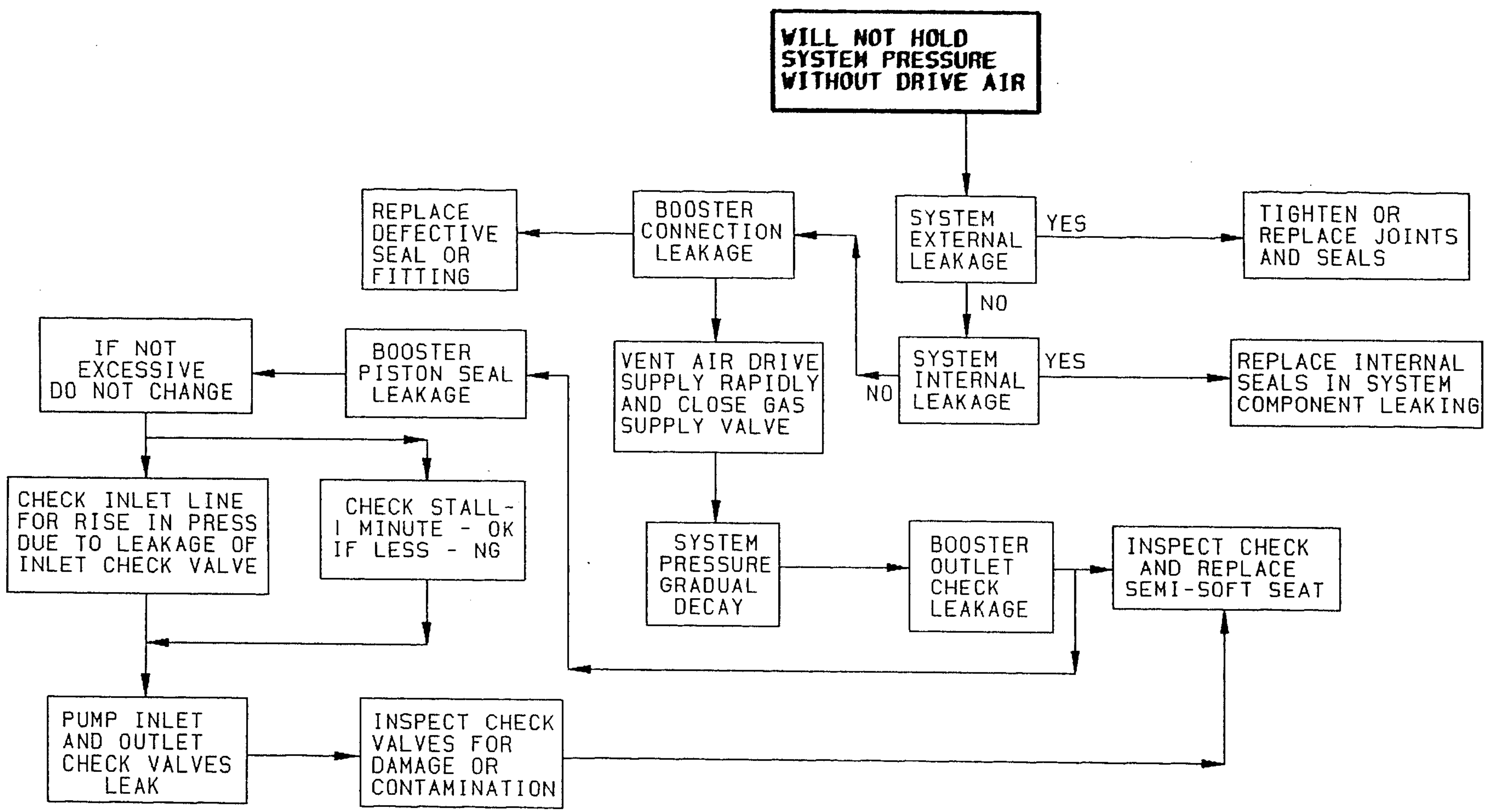
Verify no external leakage of gas at the booster and all system joints and components with the system maintained at operating pressure and the booster operational.

Shut off both the air drive pressure supply and gas supply valves. uncouple the gas supply line at the booster inlet.

If the system pressure continues to decay without stopping, and there is no evidence of leakage at the booster inlet, gas barrel vent (piston seal leakage), or rod seal leakage, then there is most likely an internal leakage in a system component.

If there is leakage at the gas inlet, then both inlet and outlet checks are leaking. If there is no leakage at the gas inlet, but the gas barrel vent shows leakage, then the outlet check and the piston seal are leaking. Verify that the leakage is sufficient to warrant service to the booster. Some small leakage of any dynamic seal can be expected. If the downstream system volume is small, a leakage rate that is tolerable for most applications may result in a small decay rate, and may not warrant the cost of repairs until it increases to a level that affects ability to pressurize in a reasonable time, or the cost of the gas being pumped becomes a significant factor (i.e.- SF6 gas). Addition of a tight sealing check valve in series with the booster outlet check valve can also eliminate the effect of this leakage and permit a greater time between service periods.

If there is no internal or external leakage in the booster, then there is an internal component leakage in the downstream system.


WILL NOT HOLD SYSTEM PRESSURE WITHOUT DRIVE AIR
SYSTEM EXTERNAL LEAKAGE
YES
TIGHTEN OR REPLACE JOINTS AND SEALS
NO
SYSTEM INTERNAL LEAKAGE
YES
REPLACE INTERNAL SEALS IN SYSTEM COMPONENT LEAKING
NO
BOOSTER CONNECTION LEAKAGE
REPLACE DEFECTIVE SEAL OR FITTING
VENT AIR DRIVE SUPPLY RAPIDLY AND CLOSE GAS SUPPLY VALVE
SYSTEM PRESSURE GRADUAL DECAY
BOOSTER OUTLET CHECK LEAKAGE
INSPECT CHECK AND REPLACE SEMI-SOFT SEAT
BOOSTER PISTON SEAL LEAKAGE
IF NOT EXCESSIVE DO NOT CHANGE
CHECK INLET LINE FOR RISE IN PRESS DUE TO LEAKAGE OF INLET CHECK VALVE
CHECK STALL- I MINUTE - OK IF LESS - NG
PUMP INLET AND OUTLET CHECK VALVES LEAK
INSPECT CHECK VALVES FOR DAMAGE OR CONTAMINATION

ERRATIC CYCLING OR SLOW-DOWN

ERRATIC CYCLING:

The symptoms of this condition are usually "uneven, irregular cycle rate. There can be a number of different causes for this condition, and all of them can be investigated without major dis-assembly.

The most likely event is "lack of adequate lubrication" on the dynamic seals in the cycling valve. If the lubrication has been "washed out" by excessively wet air, "dried out" by the use of extremely dry gas (i.e.- nitrogen), or simply dissipated by the amount of the usage of the pump with "normal" shop air, the friction of the cycling spool "O" rings can become erratic. Since the driving forces on the spool are small, this added non-uniform friction can affect shifting of the valve, causing a variable cycle rate. Since the spool is an easily accessible item, re-lubrication with Haskel lubricant (included in the seals kit) is the first action to take.

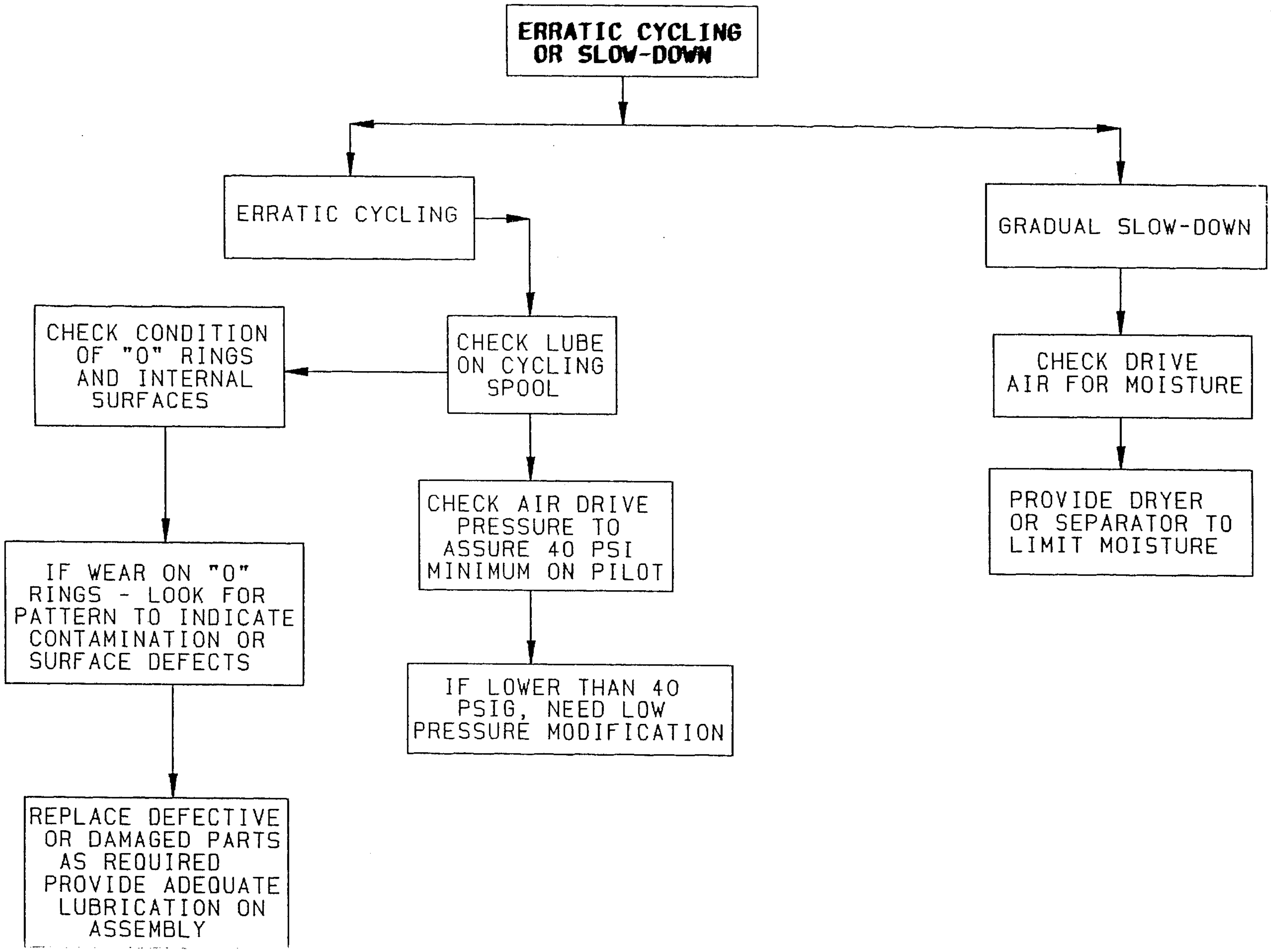
While the cycling spool is out of the valve, it is a good idea to check the condition of the "O" rings and inside diameter of the sleeve. If they show any signs of unusual wear or deterioration, they should be replaced.

If the wear pattern shows some "cutting" or "nibbling" of the "O" rings, look for contamination or surface defects, especially near the holes in the valve sleeve.

Another cause of erratic operation is "too low an air drive pressure" without a "low pressure" modification. The cycling valve does not have high driving forces with normal 100 psig drive air, and when the air pressure is below 40 psig, the force is marginal to overcome moderate friction of the 8 spool "O" rings. The "low pressure" modification gives the capability of providing the minimum 40 psi pilot pressure while maintaining a very low drive pressure. This will give consistently repeatable cycling of the valve in normal service.

GRADUAL SLOW-DOWN:

Gradual slow-down of the booster during cycling at relatively stable outlet pressures (not near stall) is usually the result of "icing" of the exhaust system due to excessively wet drive air. When an air driven booster is doing work, it is taking energy from the drive air. When this air is expanded through the exhaust system (mufflers), it cools dramatically, causing entrained moisture to freeze. The "snow" and "ice" formed tend to clog the fine screens in the muffler and back-pressure the exhaust. This "back pressure" lowers the effective pressure differential across the air drive piston, causing the booster to slow down as if it were closer to stall pressure. If allowed to continue to function, the booster will eventually slow down to the condition where the external heat input is greater than the cooling. Then the "snow" will melt, and the water will blow out of the exhaust and the cycle rate will increase. **Removal of excessive moisture from the shop air system that drives the pump is the only satisfactory solution for this problem!**


ERRATIC CYCLING OR SLOW-DOWN
ERRATIC CYCLING
GRADUAL SLOW-DOWN
CHECK LUBE ON CYCLING SPOOL
CHECK CONDITION OF "O" RINGS AND INTERNAL SURFACES
CHECK AIR DRIVE PRESSURE TO ASSURE 40 PSI MINIMUM ON PILOT
IF LOWER THAN 40 PSIG, NEED LOW PRESSURE MODIFICATION
IF WEAR ON "O" RINGS - LOOK FOR PATTERN TO INDICATE CONTAMINATION OR SURFACE DEFECTS
REPLACE DEFECTIVE OR DAMAGED PARTS AS REQUIRED PROVIDE ADEQUATE LUBRICATION ON ASSEMBLY
CHECK DRIVE AIR FOR MOISTURE
PROVIDE DRYER OR SEPARATOR TO LIMIT MOISTURE

DOES NOT PUMP EXPECTED FLOW RATES AT CYCLE RATE:

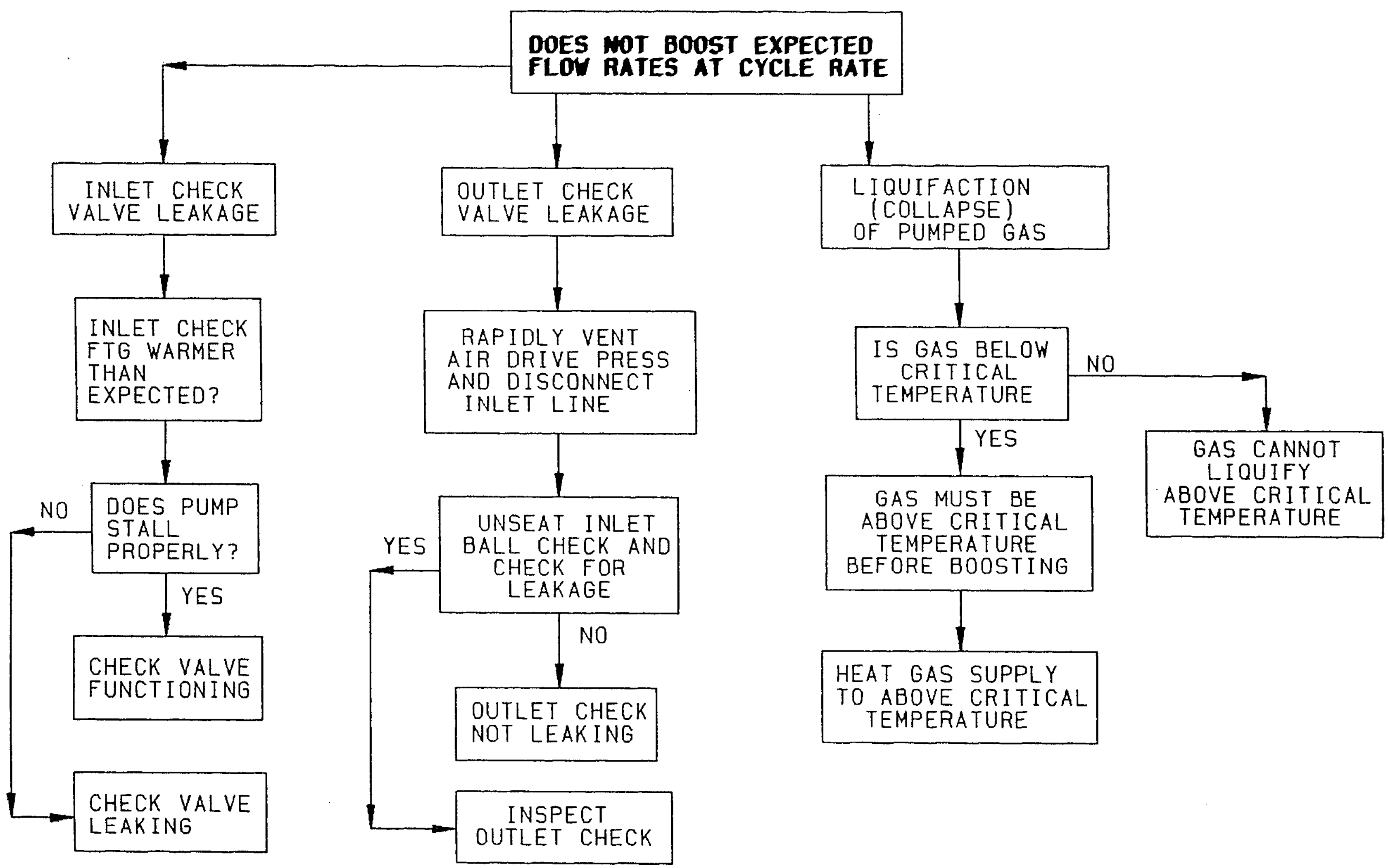
THEORY OF CAUSE:
Under normal operation of any positive displacement gas booster, the gas that enters the inlet check valve must either go out the outlet check valve into the system, or compress without generating sufficient pressure to unseat the outlet check valve (maximum compression ratio). However, there are a number of conditions that can cause this output to be less than expected.

Inlet check valve leakage will permit some of the gas to return to the gas supply line during the pressure stroke. The greater the leakage rate, the more significant and noticeable the effect on gas output flow. If the operation of the booster has been on-going for a significant time, there could be a noticeable temperature increase on the inlet fitting as compared to the supply line. This is caused by the compression heating of the gas, and the fact that the "heated" gas is travelling back and forth through the inlet check valve, along with the newly inhaled gas. Also, an easier method of detecting inlet check valve leakage (if piston seal leakage has been determined to be small), is to stall the pump against pressure and see how much time it takes to make another cycle. The check valve is not designed to be an absolute shutoff, but it should hold for at least a minute or more between cycles.

Outlet check valve leakage will permit system pressure to re-enter the gas barrel during the booster suction stroke, resulting in more of the stroke being required to lower the pressure to inlet conditions. This means that less gas is being permitted to enter the chamber on each stroke. Again, the effect is proportional to the magnitude of the check valve leakage. The easiest way of detecting this leakage, is to pressurize the system to the desired pressure, and rapidly vent the air drive pressure. Disconnect the inlet supply line and, with a small diameter clean rod, unseat the inlet ball check permitting the gas barrel to vent. If the outlet check valve is sealing properly, there will be no significant leakage once the barrel pressure has disipated. The check valves are not designed to "hold" system pressure indefinitely, so there may be a slight evidence of leakage that would be insignificant for the time of a booster cycle. Gross leakage of the outlet check valve can prevent the booster from acheiving its desired pressure, and the outlet pressure gage will experience a wide excursion of the needle with each cycle if the system volume or the line size is small.

liquifaction or "collapse" of the compressed gas is another possible cause of loss in transfer capability. This can occur if the gas being boosted is capable of liquifying at the temperature and pressure generated. When this happens, the volume of the inhaled gas suddenly becomes a small fraction of what it was in order to liquify, and there is no more compression to increase pressure. Also, if all of the liquid does not go through the check valves, it gives the effect of a substantial increase in unswept volume. This is because the residual liquid will vaporize on the suction stroke, and it will be difficult, if not impossible, to reduce the pressure below the supply pressure.

For this condition, pre-heating of the gas to above the critical temperature prior to boosting will eliminate the "collapsing" effect. This phenomenon usually occurs with "liquifyable" gases such as carbon dioxide, freon, SF-6, etc.


DOES NOT BOOST EXPECTED FLOW RATES AT CYCLE RATE
INLET CHECK VALVE LEAKAGE
INLET CHECK FTG WARMER THAN EXPECTED?
DOES PUMP STALL PROPERLY?
NO
YES
CHECK VALVE FUNCTIONING
CHECK VALVE LEAKING
OUTLET CHECK VALVE LEAKAGE
RAPIDLY VENT AIR DRIVE PRESS AND DISCONNECT INLET LINE
UNSEAT INLET BALL CHECK AND CHECK FOR LEAKAGE
YES
NO
OUTLET CHECK NOT LEAKING
INSPECT OUTLET CHECK
LIQUIFACTION (COLLAPSE) OF PUMPED GAS
IS GAS BELOW CRITICAL TEMPERATURE
NO
YES
GAS CANNOT LIQUIFY ABOVE CRITICAL TEMPERATURE
GAS MUST BE ABOVE CRITICAL TEMPERATURE BEFORE BOOSTING
HEAT GAS SUPPLY TO ABOVE CRITICAL TEMPERATURE